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(54) **METHODS FOR ONE RADIO MODULE TO LISTEN TO PAGING SIGNALS WITHOUT BREAKING THE DATA TRANSMISSION OF THE OTHER RADIO MODULE OPERATING IN THE CONNECTED MODE AND COMMUNICATION APPARATUSES UTILIZING THE SAME**

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H04W 76/04 (2009.01)
H04W 88/06 (2009.01)

(52) **U.S. Cl.**

CPC **H04W 76/048** (2013.01); **H04W 88/06** (2013.01)

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CPC H04W 76/048; H04W 52/0229; H04B 7/0413; H04B 7/024; H04B 7/0452
USPC 455/550.1, 82, 552.1
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,811,353 B2 8/2014 Chen et al.
2009/0215491 A1 8/2009 Hou et al.
2010/0075672 A1 3/2010 Jwa et al.
2010/0260147 A1 10/2010 Xing et al.

(Continued)

FOREIGN PATENT DOCUMENTS

CN 101521959 9/2009
CN 101707814 5/2010

(Continued)

OTHER PUBLICATIONS

English language translation of abstract of CN 101521959 (published Sep. 2, 2009).

(Continued)

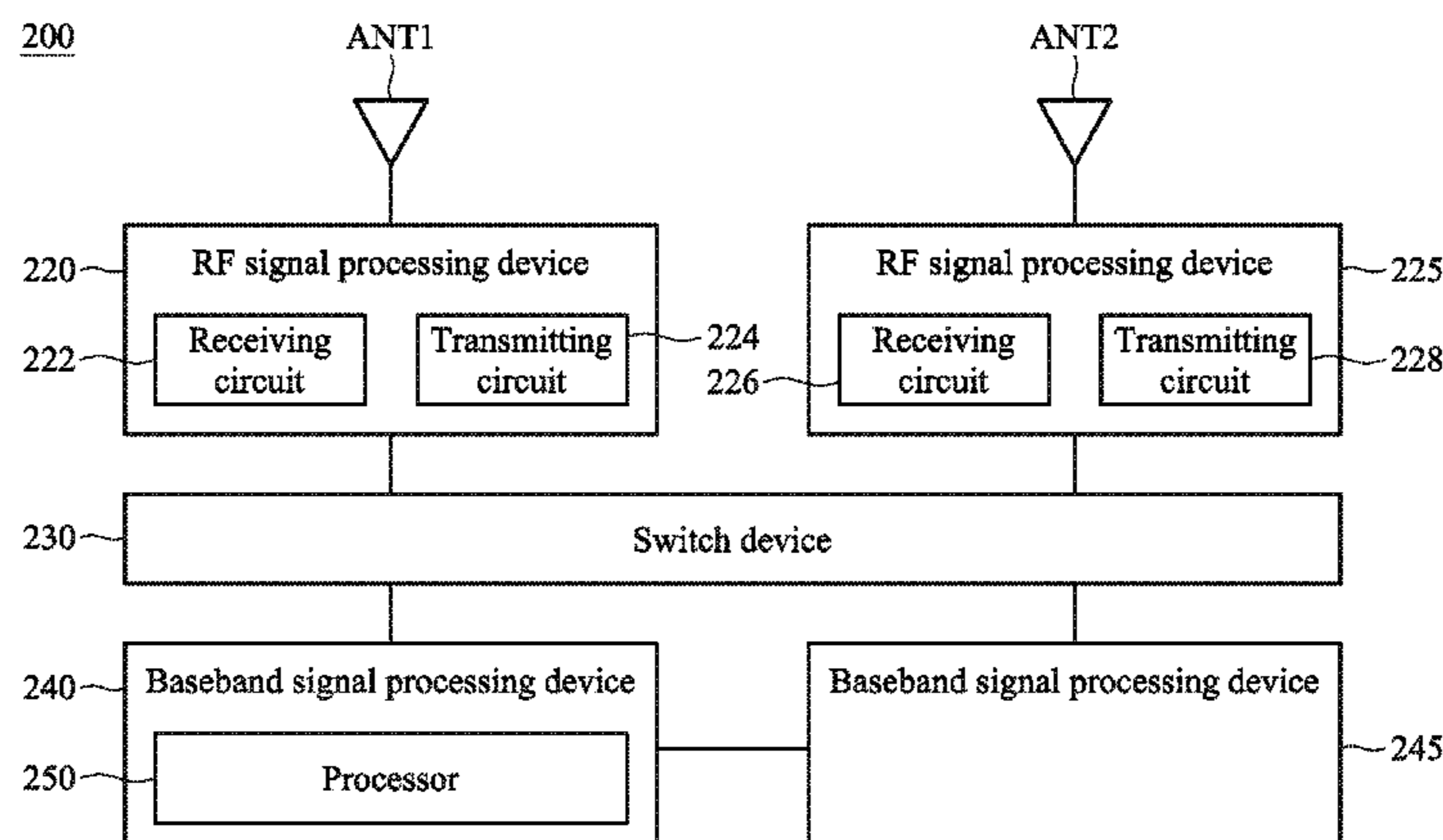
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(57) **ABSTRACT**

A communications apparatus. A first radio module communicates with a first wireless network and provides wireless communications services. A second radio module communicates with a second wireless network and provides wireless communications services. At least two antennas shared by the first radio module and the second radio module. When the first radio module operates in a connected mode and when the timing of the first radio module performing the first receiving activity coincides with the timing of the second radio module performing a second receiving activity, the first radio module reports a value of 1 for a Rank Indicator to the first wireless network at least once before the second radio module is to perform the second receiving activity, and then the second radio module uses one of the antennas to perform the second receiving activity.

17 Claims, 5 Drawing Sheets



(56)

References Cited

OTHER PUBLICATIONS

U.S. PATENT DOCUMENTS

2011/0142147 A1 6/2011 Chen et al.
2011/0207453 A1 8/2011 Hsu et al.
2013/0148636 A1 6/2013 Lum et al.
2013/0201890 A1 8/2013 Swaminathan et al.
2013/0307727 A1 11/2013 He et al.
2014/0349646 A1 11/2014 Su et al.
2014/0355505 A1* 12/2014 Su et al. 370/311
2015/0009836 A1* 1/2015 Tujkovic et al. 370/252

English language machine translation of CN 101707814 (published May 12, 2010).
English language machine translation of CN 102017451 (published Apr. 13, 2011).

* cited by examiner

FOREIGN PATENT DOCUMENTS

CN 102017451 4/2011
CN 102170680 8/2011
EP 2 432 288 3/2012
WO WO 2011/038677 4/2011

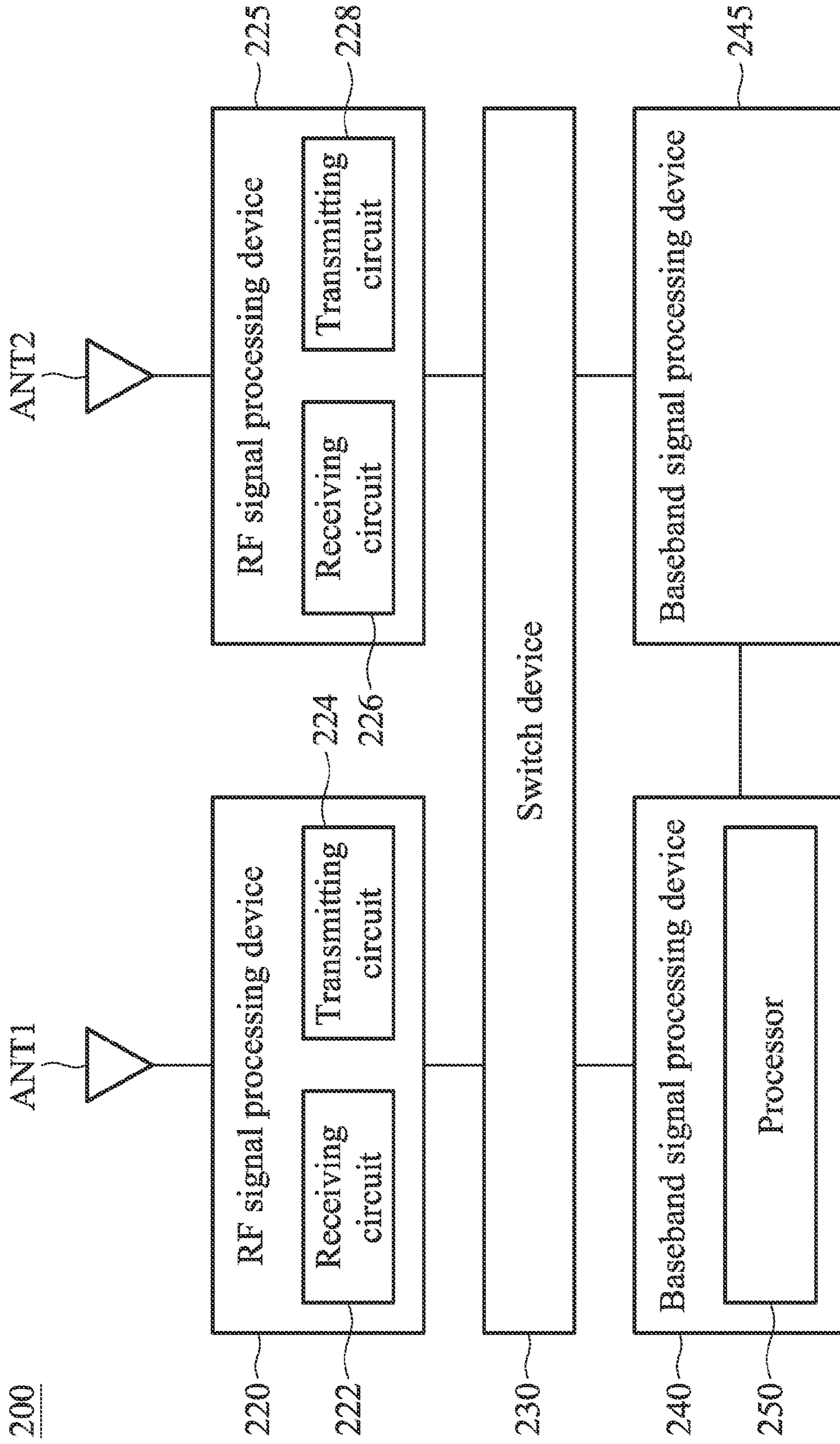


FIG. 1

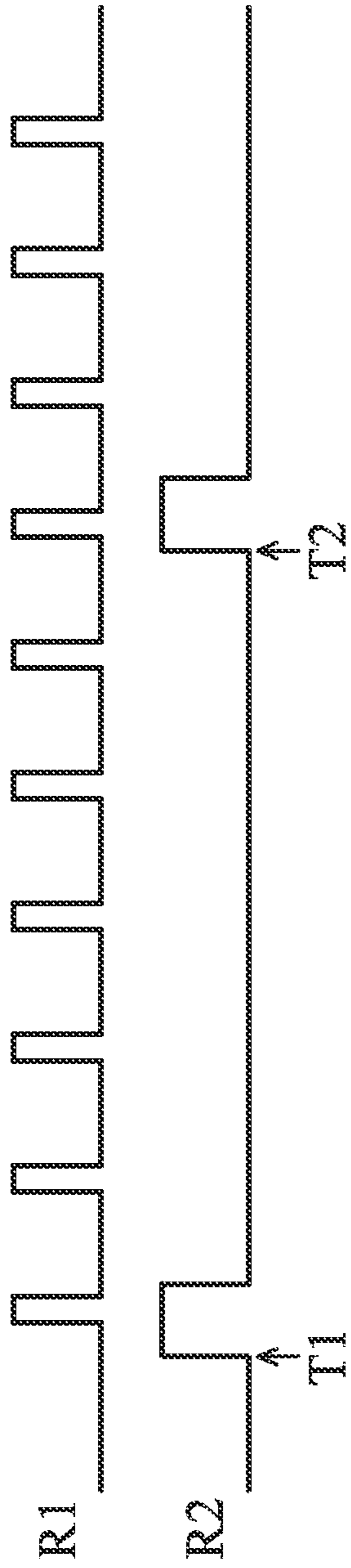


FIG. 2

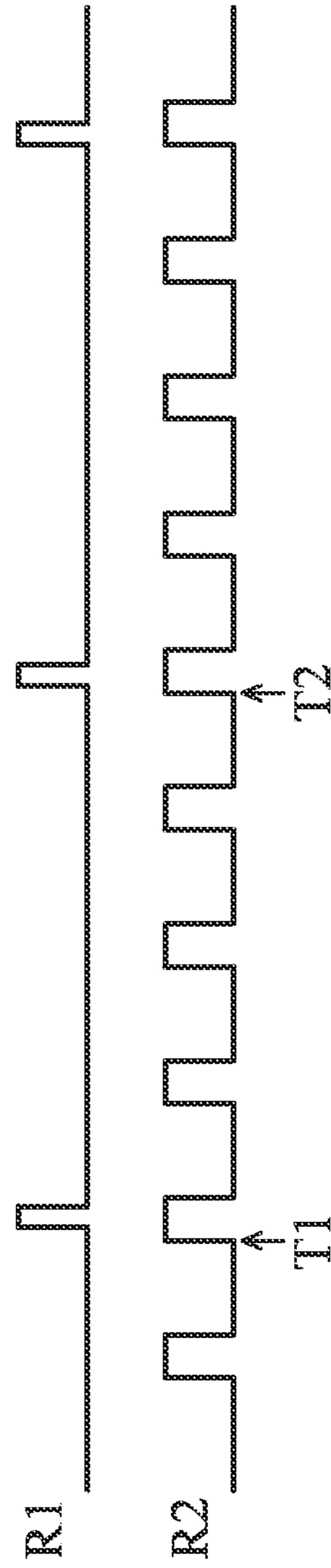


FIG. 3

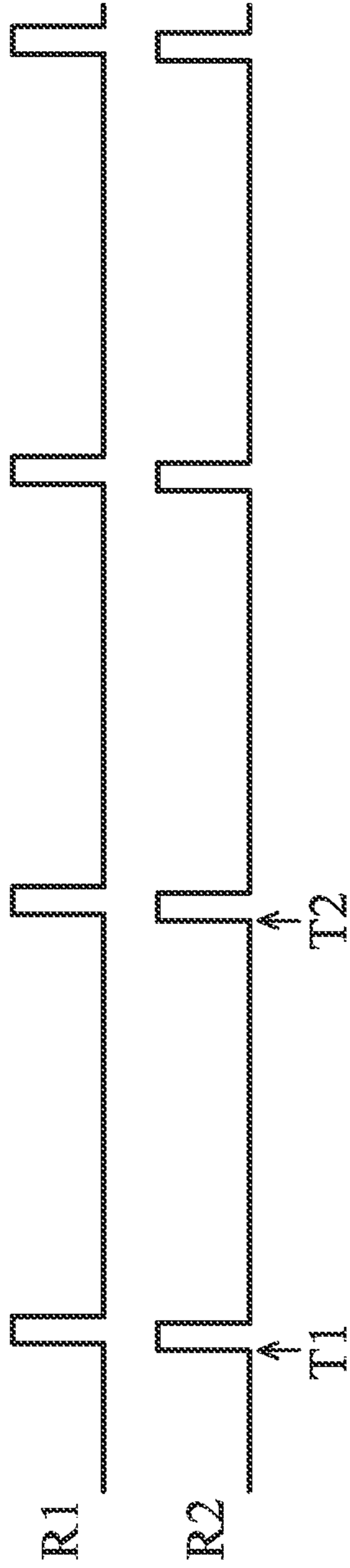


FIG. 4

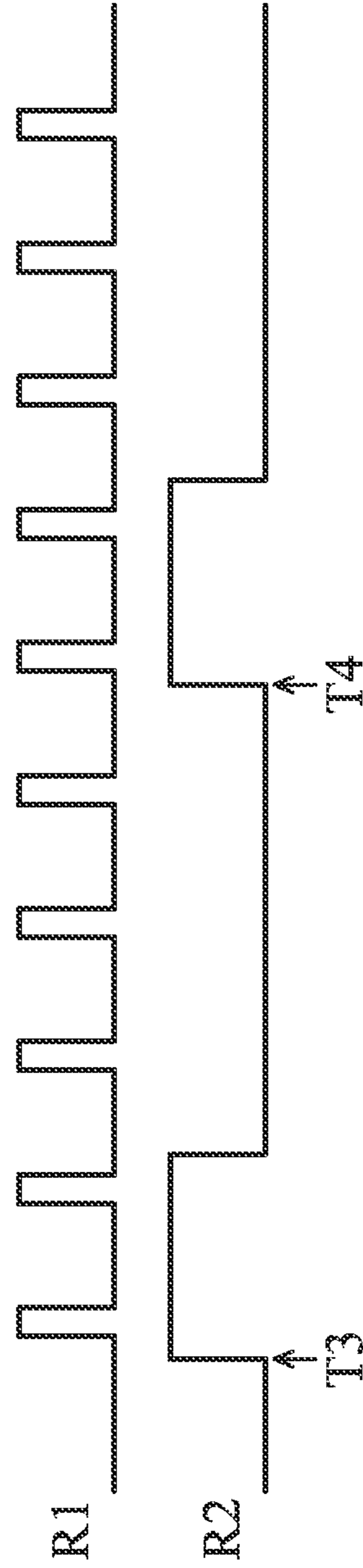


FIG. 5

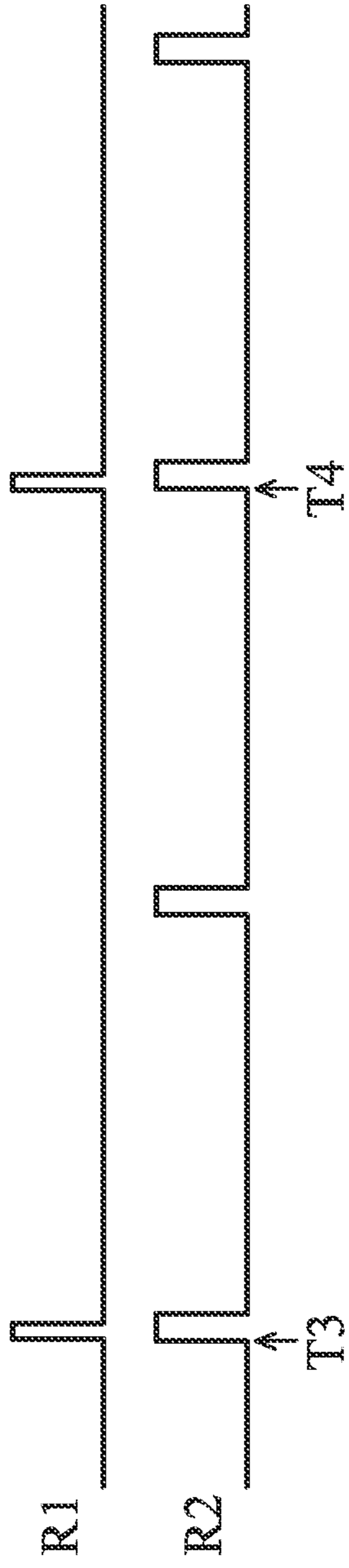


FIG. 6

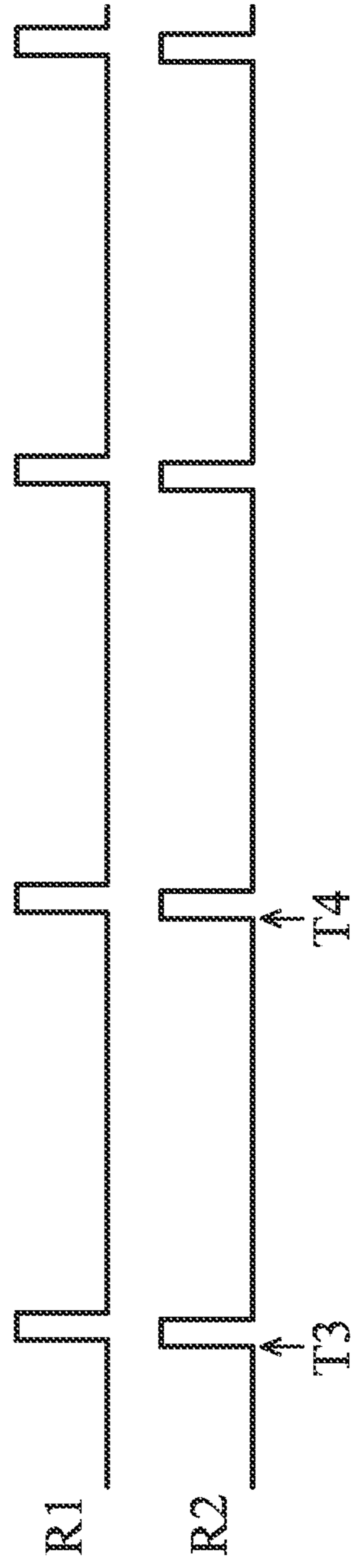


FIG. 7

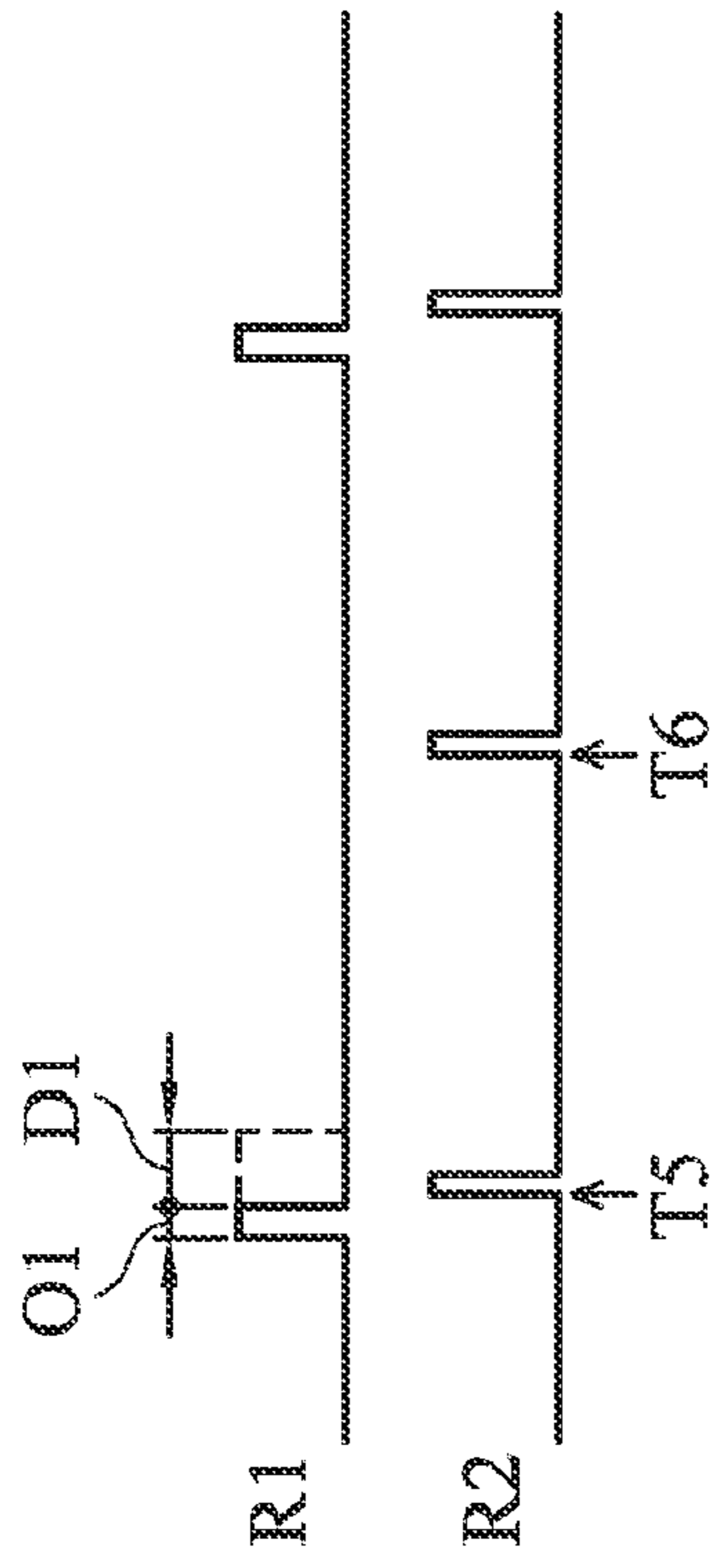


FIG. 8

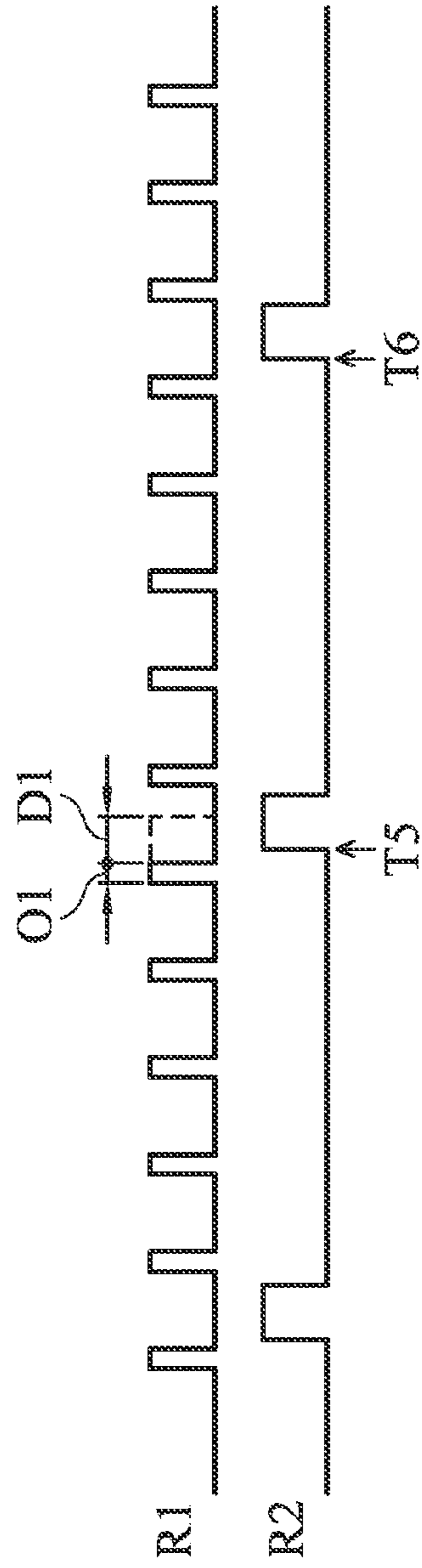


FIG. 9

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**METHODS FOR ONE RADIO MODULE TO
LISTEN TO PAGING SIGNALS WITHOUT
BREAKING THE DATA TRANSMISSION OF
THE OTHER RADIO MODULE OPERATING
IN THE CONNECTED MODE AND
COMMUNICATION APPARATUSES
UTILIZING THE SAME**

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to communication apparatuses and methods for one radio module to listen to paging signals without breaking the data transmission of the other radio module operating in the connected mode.

Description of the Related Art

The term “wireless”, normally refers to an electrical or electronic operation, which is accomplished without the use of a “hard wired” connection. “Wireless communications” is the transfer of information over a distance without the use of electrical conductors or wires. The distances involved may be short (a few meters for television remote controls) or very long (thousands or even millions of kilometers for radio communications). The best-known example of wireless communications is the cellular telephone. Cellular telephones use radio waves to enable an operator to make phone calls to another party, from many locations worldwide. They can be used anywhere, as long as there is a cellular telephone site to house equipment that can transmit and receive signals, which are processed to transfer both voice and data to and from the cellular telephones.

There are various well-developed and well-defined cellular communications technologies. For example, the Global System for Mobile communications (GSM) is a well-defined and commonly adopted communications system, which uses time division multiple access (TDMA) technology, which is a multiplex access scheme for digital radio, to send voice, data, and signaling data (such as a dialed telephone number) between mobile phones and cell sites. Furthermore, the GSM also uses frequency division multiple access (FDMA) technology. The CDMA2000 is a hybrid mobile communications 2.5G/3G (generation) technology standard that uses code division multiple access (CDMA) technology. The UMTS (Universal Mobile Telecommunications System) is a 3G mobile communications system, which provides an enhanced range of multimedia services over the 2G GSM system. Wireless Fidelity (Wi-Fi) is a technology defined by the 802.11b engineering standard that can be used for home networks, mobile phones, and video games, to provide a high-frequency wireless local area network. The Long Term Evolution (LTE) program is to bring new technology, new architecture, and new methods into the field of wireless communications, and to provide improved spectral efficiency, reduced latency, and better utilization of radio resources, thereby providing a faster user experience and richer applications and services with less associated cost.

With the advanced development of wireless communications technologies, it is now possible to provide multiple wireless communications services in compliance with different or the same Radio Access Technologies (RAT) by using multiple radio modules in one Mobile Station (MS) or User Equipment (UE). In order to provide optimal communications services for a multi-radio communications apparatus capable of supporting one radio module listening to a paging signal without breaking the data transmission of the

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other radio module, novel methods for simultaneous data transmission and standby between multiple communications systems are required.

BRIEF SUMMARY OF THE INVENTION

Communications apparatuses are provided. An exemplary embodiment of a communications apparatus comprises a first radio module, a second radio module, and at least two antennas. The first radio module communicates with a first wireless network to provide wireless communications services in compliance with a first radio access technology (RAT). The second radio module communicates with a second wireless network and provides wireless communications services in compliance with a second RAT. At least two antennas shared by the first radio module and the second radio module are for transmitting and receiving radio frequency (RF) signals to and from an air interface. When the first radio module operates in a connected mode and when the timing of the first radio module performing the first receiving activity coincides with the timing of the second radio module performing a second receiving activity, the first radio module reports a value of 1 for a Rank Indicator (RI) to the first wireless network at least once before the second radio module is to perform the second receiving activity, and then the second radio module uses one of the antennas to perform the second receiving activity.

An exemplary embodiment of a communications apparatus comprises a first radio module, a second radio module and at least two antennas. The first radio module communicates with a first wireless network to provide wireless communications services in compliance with a first radio access technology (RAT). The second radio module communicates with a second wireless network to provide wireless communications services in compliance with a second RAT. At least two antennas are shared by the first radio module and the second radio module for transmitting and receiving radio frequency (RF) signals to and from an air interface. When the first radio module operates in a connected mode and when the timing of the first radio module performing the first receiving activity coincides with the timing of the second radio module performing a second receiving activity, the second radio module uses one of the antennas to perform the second receiving activity while the first radio module uses the remaining antenna(s) to perform the first receiving activity.

A detailed description is given in the following embodiments with reference to the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

The invention can be more fully understood by reading the subsequent detailed description and examples with references made to the accompanying drawings, wherein:

FIG. 1 is an exemplary block diagram of a communications apparatus according to an embodiment of the invention;

FIG. 2 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration is shorter than the second DRX cycle duration in scenario 1 according to an embodiment of the invention;

FIG. 3 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration is longer than the second DRX cycle duration in scenario 1 according to an embodiment of the invention;

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FIG. 4 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration and the second DRX cycle duration are of equal length in scenario 1 according to an embodiment of the invention;

FIG. 5 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration is shorter than the second DRX cycle duration in scenario 3 according to an embodiment of the invention;

FIG. 6 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration is longer than the second DRX cycle duration in scenario 3 according to an embodiment of the invention;

FIG. 7 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration and the second DRX cycle duration are of equal length in scenario 3 according to an embodiment of the invention;

FIG. 8 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration is longer than the second DRX cycle duration in scenario 4 according to an embodiment of the invention; and

FIG. 9 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration is shorter than the second DRX cycle duration in scenario 4 according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The following description is of the best-contemplated mode of carrying out the invention. This description is made for the purpose of illustrating the general principles of the invention and should not be taken in a limiting sense. The scope of the invention is best determined by reference to the appended claims.

FIG. 1 is an exemplary block diagram of a communications apparatus according to an embodiment of the invention. The communications apparatus 200 may comprise at least two antennas ANT1 and ANT2 for transmitting and receiving RF signals to and from the air interface, at least two RF signal processing devices 220 and 225, a switch device 230, at least two baseband signal processing devices 240 and 245, and at least one processor 250. The RF signal processing device 220 may comprise at least a receiving circuit 222 and a transmitting circuit 224, and the RF signal processing device 225 may comprise at least a receiving circuit 226 and a transmitting circuit 228.

The receiving circuits 222 and 226 are arranged to receive RF signals from the air interface via one or both of the antennas, and process the received RF signals to convert the received RF signals to baseband signals to be processed by the baseband signal processing device 240 and 245. The transmitting circuits 224 and 228 are arranged to receive baseband signals from the baseband signal processing devices 240 and 245, convert the received baseband signals to RF signals, and transmit the RF signals to a peer communication apparatus. The receiving circuits 222 and 226 and transmitting circuits 224 and 228 may comprise a plurality of hardware elements. For example, a power amplifier, a mixer, or others. Note that in some embodiments of the invention, the RF signal processing device 220 and 225 may also comprise two receiving circuits and two transmit-

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ting circuits, and each receiving circuit and transmitting circuit may be arranged to process the RF signals received from and transmitted to one antenna. Therefore, the invention should not be limited to what is shown in FIG. 1.

The switch device 230 may switch the signal transmitting paths between the two baseband signal processing devices 240 and 245 and the RF signal processing device 220 and 225. According to an embodiment of the invention, the switch device 230 may switch the signal transmitting paths in response to the control signal issued by either the baseband signal processing device 240 or 245.

The baseband signal processing devices 240 and 245 may further process the baseband signals to convert the baseband signals to a plurality of digital signals, and process the digital signals, and vice versa. The baseband signal processing devices 240 and 245 may comprise a plurality of hardware elements to perform baseband signal processing. The baseband signal processing may comprise analog-to-digital conversion (ADC)/digital-to-analog conversion (DAC), gain adjustment, modulation/demodulation, encoding/decoding, and so on.

The processor 250 may control the operations of the baseband signal processing device 240/245, the RF signal processing device 220/225 and the switch device 230. According to an embodiment of the invention, the processor 250 may also be arranged to execute the program codes of the software module(s) of the corresponding baseband signal processing device and/or the RF signal processing device. The program codes accompanied with specific data in a data structure may also be referred to as a processor logic unit or a stack instance when being executed. Therefore, the processor may be regarded as comprising a plurality of processor logic units, each for executing one or more specific functions or tasks of the corresponding software module(s).

According to an embodiment of the invention, the RF signal processing device 220 and the baseband signal processing device 240 may be collectively regarded as a first radio module capable of communicating with a first wireless network to provide wireless communications services in compliance with a first Radio Access Technology (RAT). The RF signal processing device 225 and the baseband signal processing device 245 may be collectively regarded as a second radio module capable of communicating with a second wireless network to provide wireless communications services in compliance with a second RAT.

Note that, in some embodiments of the invention, the processor may also be configured outside of the baseband signal processing device 240, or, the communications apparatus 200 may comprise another processor configured inside of the baseband signal processing device 245 and each for controlling the operations of the corresponding baseband signal processing device, thus the invention should not be limited to the architecture as shown in FIG. 1. In addition, note that, in order to clarify the concept of the invention, FIG. 1 presents a simplified block diagram, in which only the elements relevant to the invention are shown. However, the invention should not be limited what is shown in FIG. 1.

Note further that, in some embodiments of the invention, the communications apparatus 200 may further be extended to comprise more than two antennas and/or more than two radio modules, and the invention should not be limited what is shown in FIG. 1.

According to the embodiments of the invention, since the communications apparatus is equipped with at least two radio modules and each is capable of providing predetermined communications services in compliance with a predetermined RAT, the methods of achieving the goal of

having one radio module listen to paging signals without breaking the data transmission of the other radio module operating in the connected mode are introduced.

According to an embodiment of the invention, when a receiving activity of one radio module for listening to the paging signal coincide with a receiving activity of the other radio module operating in the connected mode for receiving data, the radio module operating in the connected mode may yield the right to use one of the antennas ANT1 or ANT2 (and the corresponding receiving circuit) to the other radio module for listening to the paging signal, and may use the remaining antenna(s) (and the corresponding receiving circuit) to receive data from the wireless network based on some algorithms as will be illustrated below. Note that the “receiving activity” here refers to the radio activity of receiving RF signals from the wireless network via the antenna(s) and the receiving circuit(s).

According to a preferred embodiment of the invention, one radio module may be an LTE radio module (hereinafter called the first radio module for brevity), and the other radio module may be a GSM radio module, WCDMA radio module, CDMA2000 radio module, TDS-CDMA radio module, or others (hereinafter called the second radio module for brevity). In the following paragraphs, the algorithms of handling the coincident receiving activities are introduced in several scenarios.

Scenario 1: Idle Mode

According to an embodiment of the invention, the processor (for example, the processor 250) of the first radio module may first determine whether the first radio module operates in the RRC_connected mode. If not, the first radio module operates in an idle mode and the processor may arbitrate the right to use one of the antennas (and the corresponding receiving circuit) based on the algorithm as illustrated below.

According to an embodiment of the invention, when the timing of the first radio module performing the first receiving activity coincides with the timing of the second radio module performing the second receiving activity, the first radio module may yield the right to use one of the antennas ANT1 or ANT2 (and the corresponding receiving circuit) to the second radio module for performing the second receiving activity when the first DRX cycle duration of the first radio module in the idle mode is shorter than the second DRX cycle duration, of the second radio module.

FIG. 2 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration is shorter than the second DRX cycle duration in scenario 1, according to an embodiment of the invention. As shown in FIG. 2, R1 represents the first radio module, R2 represents the second radio module, the pulses on the right-hand side of R1 show the predetermined receiving activities to be performed by R1, and the pulses on the right-hand side of R2 show the predetermined receiving activities to be performed by R2. In this example, the timing of the first radio module’s receiving activities coincide with those of the second radio module at times T1 and T2. Therefore, the first radio module may yield the right to use one of the antennas ANT1 or ANT2 (and the corresponding receiving circuit) to the second radio module for listening to the paging signal at times T1 and T2. To be more specific, for example, the second radio module may use the antenna ANT2 and the first radio module may use the remaining antenna ANT1 at times T1 and T2. Note that, in the embodiments of the invention, the timing of performing a receiving activity may comprise the time required for setting up the receiving circuit and the corresponding soft-

ware/hardware devices, performing timing and frequency synchronization for the radio module, and the actual On period for turning on the receiving circuit, the antenna(s), and the corresponding software/hardware devices.

In addition, when the first DRX cycle duration of the first radio module in the idle mode is longer than the second DRX cycle duration of the second radio module, the first radio module may not yield the right to use one of the antennas ANT1 or ANT2 (and the corresponding receiving circuit) to the second radio module for listening to the paging signal when the timing of the first radio module performing the first receiving activity coincides with the timing of the second radio module performing the second receiving activity.

FIG. 3 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration is longer than the second DRX cycle duration in scenario 1 according to an embodiment of the invention. In this example, the timing of the first radio module’s receiving activities coincide with those of the second radio module at times T1 and T2, and the first radio module gets the right to use both the antennas ANT1 and ANT2 (and the corresponding receiving circuits) at times T1 and T2.

In addition, when the first DRX cycle duration of the first radio module in the idle mode and the second DRX cycle duration of the second radio module are of equal length, the first radio module may selectively yield the right to use one of the antennas ANT1 or ANT2 (and the corresponding receiving circuit) to the second radio module for listening to the paging signal.

FIG. 4 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration and the second DRX cycle duration are of equal length in scenario 1, according to an embodiment of the invention. In this example, the timing of the first radio module’s receiving activities coincide with those of the second radio module at times T1 and T2. Therefore, the first radio module may use the antennas ANT1 and ANT2 to perform the receiving activity at time T1 and use only the antenna ANT1 to perform the receiving activity at time T2 and thus the second radio module can use the antenna ANT2 to perform the receiving activity at time T2.

Scenario 2: Connected Mode without DRX

According to an embodiment of the invention, when the processor (for example, the processor 250) of the first radio module determines that the first radio module operates in the RRC_connected mode, the processor may further determine whether the DRX in the connected mode is applied. If not, the processor may arbitrate the right to use one of the antennas (and the corresponding receiving circuit) based on the algorithm as illustrated below.

According to an embodiment of the invention, when the first radio module operates in a connected mode without DRX (that is, the DRX is not applied), and when the timing of the first radio module performing the first receiving activity coincides with the timing of the second radio module performing the second receiving activity, the processor (for example, the processor 250) may report a value of 1 for a Rank Indicator (RI) to the first wireless network at least once before the second radio module is to perform the second receiving activity. In addition, the first radio module may further report a value for a Channel Quality Indicator (CQI) based on RI=1 and the number of receiving antennas after switching to the first wireless network at least once before the second radio module is to perform the

second receiving activity. For example, the first radio module may report the value of CQI based on the currently received control channel signals when setting RI=1. After that, the second radio module may use one of the antennas (and the corresponding receiving circuit) to perform the second receiving activity while the first radio module may use the remaining antenna(s) to perform the first receiving activity.

For example, suppose that it takes k sub-frames for the first wireless network to process and decode the data received from the communications apparatus **200** and the second radio module has to perform the second receiving activity in the 1-th sub-frame. It is preferable for the first radio module to report the value of RI as 1 to the first wireless network before the (1- k)-th sub-frame.

In addition, when the second receiving activity is completed, or before the performance of a subsequent first receiving activity, the first radio module may further report the value of the RI to the first wireless network as a preferred number of layers to be sent by the first wireless network, and further report the CQI value based on the reported RI value and the number of receiving antennas after switching. The term "layer" here refers to the number of data streams transmitted in the Multiple-Input Multiple-Output (MIMO) channels. The number of MIMO layers is referred to as the MIMO rank and the maximum number of layers or data streams is equal to the degrees of freedom provided by the MIMO channels. Note that in some embodiments of the invention, the first radio module may also report the value of the RI to the first wireless network as a preferred number of layers to be sent by the first wireless network and further reports the value of the CQI based on the reported RI value before the second receiving activity is completed, and the invention should not be limited thereto.

Scenario 3: Connected Mode with DRX and Collision Occurs in DRX on Period or the Retransmission Period

According to an embodiment of the invention, when the processor (for example, the processor **250**) of the first radio module determines that the DRX is applied, the processor may further determine whether the timing of the second radio module performing the second receiving activity coincides with the DRX On period or the retransmission period of the first radio module. If so, the processor may arbitrate the right to use one of the antennas (and the corresponding receiving circuit) based on the algorithm as illustrated below.

Here, the DRX On period refers to the time for the first radio module in the connected mode to wake up to receive the data from the first wireless network, and the retransmission period refers the time during which the first radio module is receiving the retransmitted data from the first wireless network. Note that, unlike the GSM and UMTS systems, in the LTE systems, the DRX operation can be applied not only in the idle mode, but also in the connected mode for power-saving purposes, in particular to conserve the battery power of the communications apparatus.

According to an embodiment of the invention, when the timing of the first radio module performing the first receiving activity during the DRX On period or retransmission period coincides with the timing of the second radio module performing the second receiving activity, the first radio module may yield the right to use one of the antennas ANT1 or ANT2 (and the corresponding receiving circuit) to the second radio module for performing the second receiving activity when the first DRX cycle duration of the first radio module in the connected mode is shorter than the second DRX cycle duration, of the second radio module.

FIG. 5 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration is shorter than the second DRX cycle duration in scenario 3 according to an embodiment of the invention. As the example shows in FIG. 5, the first radio module may report an RI value of 1 and a CQI value based on RI=1 and the number of receiving antennas after switching to the first wireless network before times T3 and T4 as discussed above, and then may yield the right to use one of the antennas ANT1 or ANT2 (and the corresponding receiving circuit) to the second radio module for listening to the paging signal at times T3 and T4. For example, the second radio module may use the antenna ANT2 and the first radio module may use the remaining antenna ANT1 at times T3 and T4.

In addition, when the second receiving activity is completed or before the timing of performing a subsequent first receiving activity, the first radio module may further report the value of the RI to the first wireless network as a preferred number of layers to be sent by the first wireless network, and further report the value of the CQI based on the reported value of the RI. The concepts of reporting the values of the CQI and RI are similar to those illustrated in scenario 2, and illustrations are omitted here for brevity.

In addition, when the first DRX cycle duration of the first radio module in the idle mode is longer than the second DRX cycle duration, of the second radio module, the first radio module may yield the right to use one of the antennas ANT1 or ANT2 (and the corresponding receiving circuit) to the second radio module for listening to the paging signal.

FIG. 6 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration is longer than the second DRX cycle duration in scenario 3, according to an embodiment of the invention. As per the example shown in FIG. 6, the first radio module may yield the right to use one of the antennas ANT1 or ANT2 (and the corresponding receiving circuit) to the second radio module for listening to the paging signal at times T3 and T4.

In addition, when the first DRX cycle duration of the first radio module in the connected mode and the second DRX cycle duration of the second radio module are of equal length, the first radio module may selectively yield the right to use one of the antennas ANT1 or ANT2 (and the corresponding receiving circuit) to the second radio module for listening to the paging signal.

FIG. 7 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration and the second DRX cycle duration are of equal length in scenario 3, according to an embodiment of the invention. As an example shown in FIG. 7, the first radio module may use the antenna ANT1 and ANT2 to perform the receiving activity at time T3 and use only the antenna ANT1 to perform the receiving activity at time T4 and thus the second radio module can use the antenna ANT2 to perform the receiving activity at time T4.

Scenario 4: Connected Mode with DRX and Inactive Timer

According to an embodiment of the invention, when the processor (for example, the processor **250**) of the first radio module determines that the DRX is applied and the timing of the second radio module performing the second receiving activity does not coincide with the DRX On period or the retransmission period of the first radio module, the processor further determines whether the inactivity timer of the first radio module has not expired. If so, the processor may arbitrate the right to use one of the antennas ANT1 or ANT2

(and the corresponding receiving circuit) based on the algorithm as illustrated below.

According to an embodiment of the invention, when the first DRX cycle duration of the first radio module in the connected mode with DRX is not shorter (for example, it is longer or of equal length) than the second DRX cycle duration of the second radio module, and when the timing of the second radio module performing the second receiving activity coincides with the duration when the inactivity timer has not expired, the first radio module may not yield the right to use any of the antennas ANT1 and ANT2 (and the corresponding receiving circuits) to the second radio module for listening to the paging signal.

FIG. 8 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration is longer than the second DRX cycle duration in scenario 4 according to an embodiment of the invention. As shown in FIG. 8, the time T5 for the second radio module to perform the second receiving activity coincides with the duration D1 when the inactivity timer is has not expired. Therefore, the first radio module may not yield the right to use one of the antennas ANT1 or ANT2 (and the corresponding receiving circuits) to the second radio module, and may still use the antennas ANT1 and ANT2 to perform the receiving activity during the duration D1. Note that when an inactive timer is assigned by the wireless network and when the first radio has received data during an On period O1 as shown in FIG. 8, the first radio module has to keep turning on after the On period to perform a continuous receiving activity during the duration D1. However, after finishing the continuous receiving activity during the duration D1, the first radio module may yield the right to use one of the antennas to the second radio module at the next paging occasion (for example, at time T6 as shown in FIG. 8) of the second radio module.

Note that, in cases in which the first DRX cycle duration and the second DRX cycle duration are of equal length, or in cases in which the first DRX cycle duration is longer than the second DRX cycle duration as in scenario 4, if a last paging signal is not successfully decoded by the second radio module, the first radio module may yield the right to use one of the antennas to the second radio module at the next paging occasion of the second radio module. In addition, if the second radio module didn't get the right to use the antennas in the last paging occasion, the first radio module may also yield the right to use one of the antennas to the second radio module at the next paging occasion (for example, at time T6 as shown in FIG. 9) of the second radio module.

On the other hand, when the first DRX cycle duration of the first radio module in the connected mode with DRX is shorter than the second DRX cycle duration of the second radio module, and when the timing of the second radio module performing the second receiving activity coincides with the duration when the inactivity timer has not expired, the first radio module may not yield the right to use any of the antennas ANT1 and ANT2 (and the corresponding receiving circuits) to the second radio module for listening to the paging signal. However, after the inactivity timer of the first radio module expires, the first radio module may report a value of 1 for an RI and a value for a CQI based on RI=1 to the first wireless network at least once before the timing of the second radio module is to perform a subsequent second receiving activity, which may have a performance time coinciding with that of a subsequent first receiving activity. Then, the second radio module may get the right to use one of the antennas ANT1 or ANT2 (and the corre-

sponding receiving circuits) to perform the subsequent second receiving activity while the first radio module may use the remaining antennas to perform the subsequent first receiving activity.

FIG. 9 is an exemplary timing diagram showing the receiving activities of the radio modules along the time axis when the first DRX cycle duration is shorter than the second DRX cycle duration in scenario 4, according to an embodiment of the invention. As shown in FIG. 10, the time T5 for the second radio module to perform the second receiving activity coincides with the duration D1 when the inactivity timer is has not expired. Therefore, the first radio module may not yield the right to use any of the antennas ANT1 and ANT2 (and the corresponding receiving circuits) to the second radio module, and may still use the antennas ANT1 and ANT2 to perform the receiving activity during the duration D1. However, after finishing the continuous receiving activity during the duration D1, the first radio module may yield the right to use the antennas to the second radio module at the next paging occasion (for example, at time T6 as shown in FIG. 9) of the second radio module.

According to an embodiment of the invention, the first radio module may report value of 1 for an RI value of 1 and a CQI value based on RI=1 and number of receiving antennas after switching to the first wireless network before time T6, and then may yield the right to use one of the antennas ANT1 or ANT2 (and the corresponding receiving circuit) to the second radio module for listening to the paging signal at time T6. In addition, the first radio module may further report the value of the RI to the first wireless network as a preferred number of layers to be sent by the first wireless network, and further report a value for a Channel Quality Indicator (CQI) based on the reported value of the RI and the number of receiving antennas after switching to the first wireless network at least once at the proper time after reporting a value of 1 for the RI. The proper time may, for example, when the second receiving activity is completed, or before a subsequent receiving activity of the first radio module. The concepts of reporting the RI and CQI are similar to those illustrated in scenario 2, and illustrations are omitted here for brevity.

In the embodiments of the invention, based on the algorithms in different scenarios for arbitrating the right to use the antennas and the corresponding receiving circuits as illustrated above, the goal of having one radio module be able to listen to paging signals without breaking the data transmission of the other radio module can be achieved. In addition, the transmission bandwidth of the wireless network can also be utilized more efficiently.

The above-described embodiments of the present invention can be implemented in any of numerous ways. For example, the embodiments may be implemented using hardware, software, or a combination thereof. It should be appreciated that any component or collection of components that perform the functions described above can be generically considered as one or more processors that control the function discussed above. The processor(s) can be implemented in numerous ways, such as with dedicated hardware, or with general-purpose hardware that is programmed using microcode or software to perform the functions recited above.

While the invention has been described by way of example and in terms of preferred embodiment, it is to be understood that the invention is not limited thereto. Those who are skilled in this technology can still make various alterations and modifications without departing from the scope and spirit of this invention. Therefore, the scope of the

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present invention shall be defined and protected by the following claims and their equivalents.

What is claimed is:

1. A communications apparatus, comprising:
 - a first radio module, communicating with a first wireless network to provide wireless communications services in compliance with a first radio access technology (RAT);
 - a second radio module, communicating with a second wireless network to provide wireless communications services in compliance with a second RAT; and
 - at least two antennas, shared by the first radio module and the second radio module for transmitting and receiving radio frequency (RF) signals to and from an air interface,
 wherein when the first radio module operates in a connected mode with Discontinuous Reception (DRX), when a first DRX cycle duration of the first radio module in the connected mode is not longer than a second DRX cycle duration of the second radio module and when the timing of the first radio module performing a first receiving activity coincides with the timing of the second radio module performing a second receiving activity, the first radio module reports a value which is not bigger than number of the remaining antennas for a Rank Indicator (RI) to the first wireless network at least once before the second radio module perform is to the second receiving activity, and then the second radio module uses one of the antennas to sureperform the second receiving activity.
2. The communications apparatus as claimed in claim 1, wherein the first radio module uses the remaining antenna(s) to perform the first receiving activity.
3. The communications apparatus as claimed in claim 1, wherein the first radio module further reports a value for a Channel Quality Indicator (CQI) based on the reported value for the RI and the number of receiving antennas after reporting the value which is not bigger than the number of the remaining antennas for the RI to the first wireless network.
4. The communications apparatus as claimed in claim 1, wherein when the second receiving activity is completed, the first radio module further reports the value for the RI to the first wireless network as a preferred number of layers to be sent by the first wireless network, and further reports a value for a Channel Quality Indicator (CQI) based on the reported value for the RI.
5. The communications apparatus as claimed in claim 1, wherein when the first radio module operates in the connected mode with DRX and when an inactivity timer of the first radio module has expired, the first radio module reports the value as 1 for the RI to the first wireless network at least once before the second radio module is to perform the second receiving activity, and then the second radio module uses one of the antennas to perform the second receiving activity while the first radio module uses the remaining antenna(s) to perform the first receiving activity.
6. The communications apparatus as claimed in claim 5, wherein the first radio module further reports a value for a Channel Quality Indicator (CQI) based on RI=1 and the number of receiving antennas after reporting RI=1 to the first wireless network.
7. The communications apparatus as claimed in claim 5, wherein when the second receiving activity is completed, the first radio module reports the value of the RI to the first wireless network as a preferred number of layers to be sent

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by the first wireless network, and further reports a value for a Channel Quality Indicator (CQI) based on the reported value for the RI.

8. The communications apparatus as claimed in claim 1, wherein when the first radio module operates in an idle mode and when the timing of the first radio module performing the first receiving activity coincides with the timing of the second radio module performing the second receiving activity, the second radio module uses one of the antennas to perform the second receiving activity while the first radio module uses the remaining antenna(s) to perform the first receiving activity.
9. The communications apparatus as claimed in claim 1, wherein the reported value for the RI is 1.
10. A communications apparatus, comprising:
 - a first radio module, communicating with a first wireless network to provide wireless communications services in compliance with a first radio access technology (RAT);
 - a second radio module, communicating with a second wireless network to provide wireless communications services in compliance with a second RAT; and
 - at least two antennas, shared by the first radio module and the second radio module for transmitting and receiving radio frequency (RF) signals to and from an air interface,
 wherein when the first radio module operates in a connected mode with Discontinuous Reception (DRX) and when the timing of the first radio module performing a first receiving activity coincides with the timing of the second radio module performing a second receiving activity, the second radio module uses one of the antennas to perform the second receiving activity while the first radio module uses the remaining antenna(s) to perform the first receiving activity when a first DRX cycle duration of the first radio module in the connected mode is not longer than a second DRX cycle duration of the second radio module.
11. The communications apparatus as claimed in claim 10, wherein when the first radio module operates in the connected mode without DRX, the first radio module reports a value of 1 for a Rank Indicator (RI) and a value for a Channel Quality Indicator (CQI) based on RI=1 and the number of receiving antennas to the first wireless network at least once before the second radio module is to perform the second receiving activity, and then the second radio module uses one of the antennas to perform the second receiving activity while the first radio module uses the remaining antenna(s) to perform the first receiving activity.
12. The communications apparatus as claimed in claim 11, wherein when the second receiving activity is completed, the first radio module further reports the value of the RI to the first wireless network as a preferred number of layers to be sent by the first wireless network, and further reports the value of the CQI based on the reported value of the RI.
13. The communications apparatus as claimed in claim 10, wherein when the first radio module operates in the connected mode with DRX, the first radio module reports a value of 1 for a Rank Indicator (RI) and a value for a Channel Quality Indicator (CQI) based on RI=1 and the number of receiving antennas to the first wireless network when the first DRX cycle duration of the first radio module in the connected mode is shorter than a second DRX cycle duration of the second radio module.
14. The communications apparatus as claimed in claim 13, wherein when the second receiving activity is completed, the first radio module further reports the value of the

RI to the first wireless network as a preferred number of layers to be sent by the first wireless network, and further reports the value of the CQI based on the reported value of the RI.

15. The communications apparatus as claimed in claim 5
10, wherein when the first radio module operates in a connected mode with DRX and when an inactivity timer of the first radio module has expired, the first radio module reports a value of 1 for a Rank Indicator (RI) and a value for a Channel Quality Indicator (CQI) based on RI=1 to the first 10
 wireless network when a first Discontinuous Reception (DRX) cycle duration of the first radio module in the connected mode is shorter than a second DRX cycle duration of the second radio module.

16. The communications apparatus as claimed in claim 15
15, wherein when the second receiving activity is completed, the first radio module further reports the value of the RI to the first wireless network as a preferred number of layers to be sent by the first wireless network, and further reports the value of the CQI based on the reported value of 20
 the RI.

17. The communications apparatus as claimed in claim **10**, wherein when the first radio module operates in an idle mode and when the timing of the first radio module performing the first receiving activity coincides with the timing 25
 of the second radio module performing the second receiving activity, the second radio module uses one of the antennas to perform the second receiving activity while the first radio module uses the remaining antenna(s) to perform the first receiving activity. 30

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